Water Availability of Soil and Growth of Maize on Ultisols Due to Amelioration with Coconut Shell Biochar and Leuchaena Compost

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Abstract. Ultisol sub-optimal acid dry land indicates sick soil, because the organic matter content is low so it requires amelioration so that it can be recovered and become productivity. Amelioration of acid dry land through the application of biochar and compost has been carried out in Tangkit Village, Sungai Gelam District, Muaro Jambi Regency from May to October 2022. The purpose of the study was to determine the improvement of water available which was applied with coconut shell biochar and *leuchaena* compost, as well as its effect on the growth of maize plants. The research implementation method used a randomized block design with three groups and 10 experimental units. The experimental formula is: a0: without ameliorant + inorganic fertilizer according to full dose the recommendations; a1: biochar 10 tons + compost 5 tons/ha + inorganic fertilizer full dose; a2: biochar 5 tons/ha + compost 10 tons/ha + inorganic fertilizer full dose recommendation; a3: compost 10 tons/ha + inorganic fertilizer 1/2 dose recommendation; a4: 10 ton/ha biochar + inorganic fertilizer ½ dose recommendation; a5: biochar 5 tons/ha + compost 5 tons/ha + inorganic fertilizer 1/2 dose recommendation; a6: biochar 5 tons/ha + compost 5 tons/ha + inorganic fertilizer1/2 dose recommended; a7: compost 10 tons/ha + inorganic fertilizer as ½ dose recommended; a8: 10 tons/ha biochar + inorganic fertilizer full dose recommended; a9: compost 10 tons/ha _ + biochar 10 tons/ha + inorganic fertilizer ½ dose recommendation. The data obtained from this study were analyzed using Anova and continued with Duncan's test. The observed variables were soil water retention at pF1,0, pF2.54, pF 3.1 and pF 4.2. Field water content, field capacity water content, available water and permanent wilting point water content, as well as maize plant growth. The results showed that: (1) ameliorant coconut shell biochar and *lauchaena* compost increased the availability of water compared to no treatment, either combined or alone; (2) the combination of biochar 5 tons/ha + compost 10 tons/ha is effective in increasing water available compared to treatment at biochar 10 tons/ha + compost 5 tons/ha and compost 10 tons/ha + biochar 10 tons/ha. (3) the ameliorant compost and biochar given increase the growth of maize plants, and can reduce the need for chemical fertilizers by up to 50%.

Keywords: Ameliorant · Coconut shell biochar · Leuchaena compost · Maize · Sub optimal land

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1 Introduction

Ultisol is a marginal soil dominantly found in Jambi. Ultisols are an order of dry land soils, in term that are sub-optimal because they have low organic matter content, high acidity, leveling of nutrient, and have soil physical properties that do not support intensive agricultural production [1]. However, it has been intensively cultivated for agricultural lands, lately.

Thus, water storage is the main factor limiting the yield potential of agricultural crops on soil degraded. The main characteristics of degraded land are: (1) low organic matter content; (2) experiencing nutrient leveling; (3) low fertility, (4) high erosion, (5) frequent droughts or floods, and (6) high soil acidity. In the last decades, new resources and improved agricultural management strategies have emerged for mitigating global GHG emissions [2].

Agricultural activities (e.g., land use change, soil tillage, and use of synthetic N fertilizers) account for 14% of greenhouse gas (GHG) emissions of anthropogenic origin [3, 4, 5], which has intensified alterations in the planet's hydrological regimes in response to global climate change [6, 7]. These modifications may bring new challenges for food production in some areas, including Indonesial, where more than 80% of production areas are rainfed [8]. Thus, water shortage is the main factor limiting the yield potential of agricultural crops [9, 10].

One of these strategies is the use of biochar, a recalcitrant organic material that is produced through the thermal degradation of biomass in a low oxygen environment, to promote soil carbon (C) accretion [2, 11]. However, the benefits of biochar go beyond C sequestration, affecting other multiple soil properties and processes [12, 13, 14]. These benefits include increasing soil pH [15], cycling and plant-availability of nutrients [16], cation exchange capacity [17], adsorption of potentially toxic elements [18], and microbial biodiversity [19]. In addition, a recent global meta-analysis showed the potential of biochar use for enhancing soil physical properties, such as reducing bulk density and increasing water retention capacity [20], especially in coarse-textured soils under temperate climate [21, 22, 23]. However, there is a paucity of studies investigating the potential of biochar to increase water retention capacity in tropical soils [24, 25, 26].

Application of compost is one efficient way to increase soil organic matter level and indirectly improve soil structure and hydrological function [27, 28]. A large number of studies have documented positive effects of compost application on different soil physical and hydrological attributes: total porosity [29], bulk density [30], soil resistance to penetration [31], pore size distribution [32], aggregation and aggregate stability [26, 33, 34], water retention capacity [35, 36], and saturated and unsaturated hydraulic conducti7ity [37, 38]. As a consequence of improved water retention capacity, compost addition increases the plant available water capacity (PAWC) of soils [39]. Comparative analysis of twenty-five studies showed that compost incorporation had positive effects on degraded urban soils in terms of reduced compaction, enhanced infiltration and hydraulic conductivity, and increased water content and PAWC [37].

2 Materials and Methods

A field experiment was conducted in Tangkit village, Muaro Jambi Districs from May to October 2022. The research was carried out in dry land Ultisol owned by farmers in Tangkit Village, Sungai Gelam District, Muaro Jambi Regency. Soil analysis was carried out at the Laboratory of Soil Fertility, Faculty of Agriculture, University Jambi.

The soil samples used for initial analysis had not been treated with biochar or compost. Initial analysis of the soil physical and chemical properties were carried out in the topsoil (0–20 cm). The variables observed were soil organic matter, bulk density, total porosity, field capacity (FC), available water content (AWC), wilting permanent water content (WP), growth maize of plant.. The experimental design used in this study was a Randomized Block Design. The treatments were arranged in 10 treatment and 3 times. The combination formula used are: a0 = no treatment; a1 = biochar 10 ton/ha + compost 5 ton.ha + anorganic fertilizer ½ doze rekom, a2 = biochar 5 ton/ha + compost 10 ton.ha + anorganic fertilizer ½ doze rekom; a3 = compost 10 ton/ha + anorganic fertilizer ½ doze rekom; a4 = biochar 10 ton/ha + anorganic fertilizer ½ doze ekom; a5 = biochar 5 ton/ha + compost 5 ton/ha + anorganic fertilizer ½ doze; a6 = biochar 5 ton/ha + compost 5 ton/ha + anorganic fertilizer full doze; a7 = compost 10 ton/ha + anorganic fertilizer full doze; a8 = biochar 10 ton/ha + anorganic fertilizer full doze; a9 = biochar 10 ton/ha + compost 10 ton/ha + anorganic fertilizer ½ doze.

While the soil samples used for the final analysis were taken from each plot, then compiled from the area around the roots. While the soil samples used for the final analysis were taken undistrub soil sample and disturb soil sample on each plot. Soil physical properties observed in the final soil sample were soil retention on pF1,0; pF2,0; pF2,54 and pf 4,2. Soil properties observed in the final soil sample were were soil organic matter, bulk density, total porosity, field capacity (FC), available water content (AWC), wilting permanent water content (WP), growth maize of plant.

The method of soil analysis is using standardized by the Indonesian Soil Research Institute. Data resulted were statistically analyzed using F-test, and continued using Duncan Multiple Range Test at α 5% level of significance if the F-calculated > F-table.

3 Result and Discussion

3.1 Physicochemical Properties of Ultisol

The results of preliminary analysis of the chemical properties of Ultisols and biochar were presented in Table 1. The soil of the research location has characteristics that do not support agricultural productivity (Table 1). The Ultisol soil where the study was conducted had low organic matter content, reacted high acidity, had poor physical properties, low water availability, as well as penetration resistance which did not support the growth of food crops.

3.2 Effect of Coconut Shell Biochar and Leuchaena Compost on Soil Organic Matter (OM), Soil Bulk Density (BD) and Total Porosity (TP)

The results showed that the application of ameliorant either in combine or alone can increase the organic matter content of the soil. The higher the dose of ameliorant given,

Table 1. Physicochemical attributes of initial soil

Properties	Initial Soil	Criteria
C-organic (%)	1,12	Low *
pH (H2O)	4,78	Acid*
Organic Matter (%)	1,93	Low*
Bulk Density (g/cm^3)	1,57	High*
Total Porosity (%)	41,88	Low*
Particle Density (g/cm^3)	2,84	High*
Textur: Sand %)	48,40	
Silt (%)	18,40	Sandy clay loam
Clay (%)	33,20	
Water content (%)	23,12	Low*
Field Capasity (%)	28,36	
Available Water (%)	8,88	Low**
Wilting Point Water Content (%)	19,48	
Permeability (cm/jam^{-1})	6,03	Slow**
Infiltrasion Rate (cm/jam^{-1})	14,2	Medium**
% Agregate (%)	43,85	Low*
Stability Agregat (%)	52,41	Low*

the greater the organic matter content of the soil. Provision of ameliorant 20 tons/ha (combination of biochar 10 tons/ha - compost 10 tons/ha). Amelioration with the combination of biochar 5 tons/ha and compost 10 tons/ha was not significantly different from the combination of biochar 10 tons/ha and compost 10 ons/ha. The results also showed that amelioration at a dose of 10 tons/ha both in combination and alone significantly increased soil organic matter (OM) content (Table 2).

The application of biochar and compost either in combine or alone reduces the soil bulk density, the higher the ameliorant dose, the lower the soil bulk density (BD). These results indicate that amelioration using biochar and compost can improve soil aggregation so that the soil is more dense, which is indicated by the lower soil bulk density.

The results showed that amelioration with biochar and compost increased the total porosity (TP) compared to no treatment. This is in line with the decrease in bulk density due to the application of biochar and compost.

Application of compost is one efficient way to increase soil organic matter level and indirectly improve soil structure and hydrological functions [40, 41]. A large number of studies have documented positive effects of compost application on different soil physical and hydrological attributes; total porosity [42], bulk density [30].

The application of biochar and compost either in combine or alone reduces the soil bulk density, the higher the ameliorant dose, the lower the soil bulk density (BD).

Table 2. Organic matter content, bulk density and total porosity soil due to the application of coconut shell biochar and leuchaena compost

Treatment	OM (%)		BD g/cm^3		TP (%vol)	
A0	1,83	e	1,38	a	50,17	d
A1	3,57	bc	1,19	bc	55,40	bc
A2	3,90	ab	1,16	d	57,68	ab
A3	3,25	c	1,19	cd	54,41	bc
A4	3,23	c	1,19	bc	54,26	cd
A5	2,50	de	1,22	b	54,04	d
A6	2,83	cde	1,20	b	52,00	d
A7	3,50	bc	1,17	cd	56,91	bc
A8	3,40	c	1,19	bc	55,34	bc
A9	4,27	a	1,15	d	58,52	ab

Note: a0 = no treatment
a1 = biochar 10 ton/ha + compost 5 ton.ha+ anorganic fertilizer ½ dose rekom
a2 = biochar 5 ton/ha + compost 10 ton.ha + anorganic fertilizer ½ dose rekom
a3 = compost 10 ton/ha + anorganic fertilizer ½ dose rekom
a4 = biochar 10 ton/ha + anorganic fertilizer ½ dose ekom
a5 = biochar 5 ton/ha + compost 5 ton/ha + anorganic fertilizer ½ dose
a6 = biochar 5 ton/ha + compost 5 ton/ha + anorganic fertilizer full dose
a7 = compost 10 ton/ha + anorganic fertilizer full dose
a8 = biochar 10 ton/ha + anorganic fertilizer full dose
a9 = biochar 10 ton/ha + compost 10 ton/ha + anorganic fertilizer ½ dose
The numbers followed by the same letters in the same column are not significantly different from the Duncan's test at 5% level

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Figure 1 shows the pattern of changes in soil organic matter content due to amelioration using coconut shell biochar and leuchaena compost. Its shows that the organic matter content was higher in the soil treated with biochar and compost, both in combine and alone.

Changes in soil bulk density to amelioration with coconut shell biochar and Leuchaena compost (Fig. 2), showed a lower bulk density pattern in the treated soil compared to the untreated soil. A9 and A2 treatments were lower than other treatments amelioration of coconut shell biochar and leuchaena compost showed a pattern of changes in total sporosity as shown in Fig. 3. Total porosity was higher in soils that were treated with a combine of biochar and compost or alone compared to those without treatment. A9 treatment than other treatments, followed by A2 and A1.

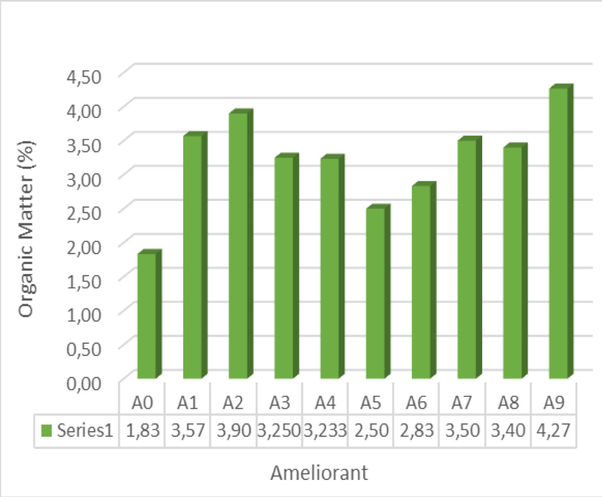

Fig. 1. The pattern of changes in soil organic matter content due to amelioration using coconut shell biochar and leuchaena compost

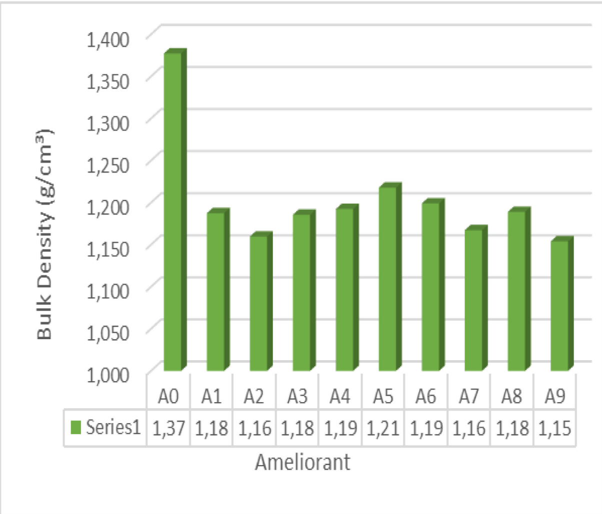

Fig. 2. The pattern of changes in soil bulk density due to amelioration using coconut shell biochar and leuchaena compost

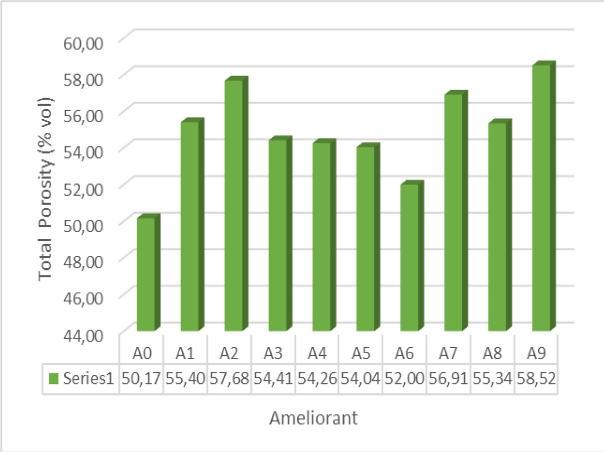

Fig. 3. The pattern of changes in soil total porosity due to amelioration using coconut shell biochar and leuchaena compost

3.3 Effect of coconut shell biochar and Leuchaena compost on water content of field capasity (FC), available water content (AWC) and Wilting Point Water Content (WP-WC)

The results showed that amelioration with coconut shell biochar and leuchaena compost increased the water content of the field capacity (Table 3). The ameliorant combine of 10 tons/ha of biochar and 10 tons/ha of leuchaena compost was higher than the other treatments, but not different from the combine treatment of 5 tons/ha of biochar and 10 tons/ha of compost. The treatments at a dose of 10 tons/ha, both in combination and alone, were not significantly different from each other.

The effect of aplication coconut shell biochar and leuchaena compost on available water content (Table 3), shows that the combine of 10 tons/ha of biochar and 10 tons/ha of leuchaena compost showed the highest available water content, but not significantly different from the combine of 5 tons/ha of biochar and leuchaena compost 10 tons/ha. This shows that the higher the dose of ameliorant given, the higher the water content available in the soil.

The effect of aplication coconut shell biochar and leuchaena compost either in combine or alone on the water content of the permanent wilting point showed no significant difference. This is presumably because the permanent wilting point is not affected by compost ameliorant or biochar ameliorant, but is more influenced by soil texture.

The results showed that amelioration using coconut shell biochar and lamtoro compost affected soil water retention (Fig. 4). Soil water retention might also be mediated by adsorption mechanisms, apart from capillarity. Biochar particles are able to retain water particles through this mechanism due to their high specific surface area per unit of mass. Likewise, the effect of compost given causes the capillary pores to increase so that soil water retention also increases. Biochar and compost combine can soil water retention compared with no treatment.

Table 3. Field capacity (FC), available water content (AWC) and permanent wilting point water content (PW-WC) due to the application of coconut shell biochar and leuchaena compost

Treatment	FC-WC (%)		AWC (%)		WP-WC (%)	
A0	28,90	e	10,60	a	18,30	a
A1	33,77	bc	13,70	c	20,07	a
A2	34,90	ab	16,63	d	18,27	a
A3	32,50	c	13,13	b	19,37	a
A4	31,73	e	12,79	b	19,27	a
A5	31,63	e	12,53	b	19,10	a
A6	29,07	e	11,00	ab	18,07	a
A7	33,13	c	13,63	c	20,17	a
A8	32,97	c	13,33	c	19,63	a
A9	35,03	a	16,67	d	18,37	a

Note: a0 = no treatment
a1 = biochar 10 ton/ha + compost 5 ton.ha + anorganic fertilizer ½ dose rekom
a2 = biochar 5 ton/ha + compost 10 ton.ha + anorganic fertilizer ½ dose rekom
a3 = compost 10 ton/ha + anorganic fertilizer ½ dose rekom
a4 = biochar 10 ton/ha + anorganic fertilizer ½ dose rekom
a5 = biochar 5 ton/ha + compost 5 ton/ha + anorganic fertilizer ½ dose
a6 = biochar 5 ton/ha + compost 5 ton/ha + anorganic fertilizer full dose
a7 = compost 10 ton/ha + anorganic fertilizer full dose
a8 = biochar 10 ton/ha + anorganic fertilizer full dose
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The numbers followed by the same letters in the same column are not significantly different from the Duncan's test at 5% level

Application of compost is one efficient way to increase soil organic matter level and indirectly improve soil structure and hydrological functions [28, 43]. A large number of studies have documented positive effects of compost application on different soil physical and hydrological attributes: total porosity [29], bulk density [47, soil resistance to penetration [44], pore size distribution [32], aggregation and aggregate stability [33, 34, 43], water retention capacity [45, 46], and saturated and unsaturated hydraulic conductivity [37, 38]. As a consequence of improved water retention capacity, compost addition increases the plant available water capacity (PAWC) of soils [47]. Comparative analysis of twenty-five studies showed that compost incorporation had positive effects on degraded urban soils in terms of reduced compaction, enhanced infiltration and hydraulic conductivity, and increased water contentand PAWC [48, 49].

Hysteresis of the water retention curve affected the estimation of capacity-based indicators of soil physical quality (SPQ) and pore volume distribution parameters of a sandy loam soil amended with compost obtained from orange juice processing wastes and garden cleaning. The sorption process involved larger and more heterogeneous pores thus resulting in capacity-based indicators linked to soil aeration (Pmac and AC) that were generally higher and plant water availability indicators (PAWC and RFC) were generally lower than those determined from desorption data. [50].

The results of the analysis of plant height are presented in Fig. 5. Based on the research data, the application of biochar coconut shell and compost poutry manure combine or single increased the height of maize plants. While the actual dosage increased the plant height of the maize plant.

Application of coconut shell biochar and leuchaena compost either in combine or alone significantly increased the growth rate of corn plants compared to no treatment (Fig. 4). The higher the dose of ameliorant given the better plant growth, treatment A9 showed a better growth rate than other treatments, followed by treatment A2. This is because treatments A9 and A2 have better water availability than the other treatments (Table 3), and also have better physical properties (Table 2).

The higher the dose of ameliorant given the better plant growth, treatment A9 showed a better growth rate than other treatments, followed by treatment A2. This is because treatments A9 and A2 have better water availability than the other treatments (Table 3), and also have better physical properties (Table 2).

Supporting previous researchers, application of biochar from the cocoa shell and oil palm shell on ultisols increased the plant height, the number of leaves, and the dry weight of maize, (3) application of biochar from the cocoa shell at a dosage of 20% was significantly improved CEC of Ultisols (4) application of biochar from the cocoa shell in top soil at a dosage of 30% significantly improved the soil organic C of Ultisol, (6) application of biochar from oil palm shell at a dosage of 10% significantly increased maize plant growth [51].

This shows that the provision of biochar with a low dosage had an effect on the plant height and the dry weight of maize plants. The plant height at the end of the vegetative period indicated that the plants had flowered more than 90%, indicating that the treatments A9, A2 and A1 were higher than other treatments.

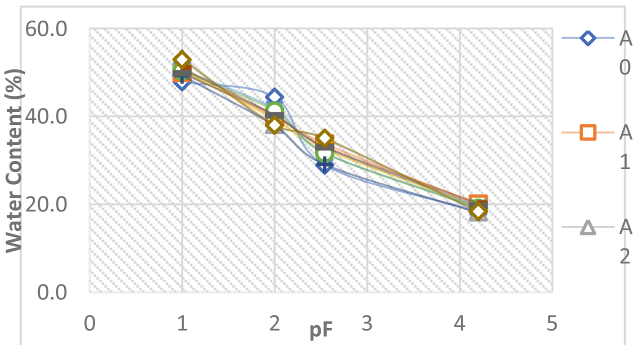

Fig. 4. Soil water retention curves (SWRCs) due to the application of coconut shell biochar

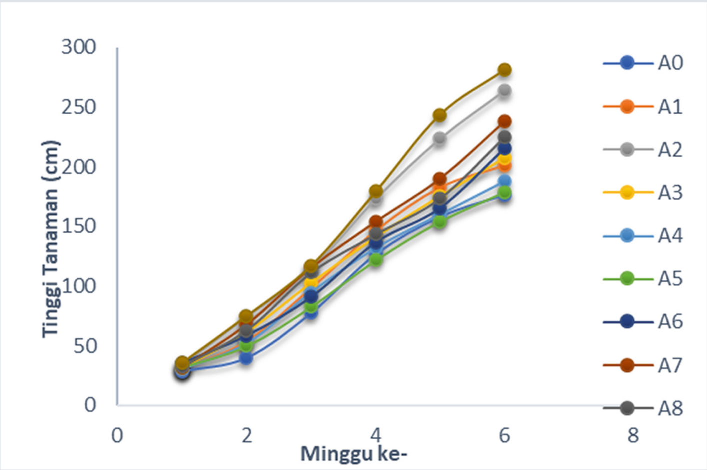

Fig. 5. High of Maize due to coconut shell biochar and leuchaena compost

4 Conclusion

Based on the results of the research conducted, it can be concluded that the application of coconut shell biochar ameliorant and lauchaena compost either combine and or salone increases the availability of water in the soil. The higher the dose of ameliorant given, the higher the availability of water. However, the most effective ameliorant treatment was amelioration with combine 5 tons/ha of coconut shell biochar and 10 tons/ha of leuchaena compost.

Amelioration with biochar and compost increased the growth of maize compared to no treatment. The ameliorant used can reduce the need for inorganic fertilizers by up to 50%. The growth rate of mauze plants was higher with the higher dose of ameliorant given.

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Authors' Contributions. Conceptualization, En; methodology. En, D.L.; formal analysis, En, D.L. and investigation, En, D.L..; data curation, En. D.L.; writing—original draft, En, D.L.; preparation, En, D.L., D..; writing—review and editing. En, D.L. All authors have read and agreed to the published version of the manuscript.

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